PRELIMINARY EXPERIMENTS IN THE PHYSIOLOGY AND PSYCHOLOGY OF READING.

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The present article is a report of experiments preliminary to a study of the Psychology of Reading, the general purpose of the study being to learn as far as may be just what occurs physiologically and psychically, in reading a printed page.

A series of experiments was first undertaken to decide the comparative merits of printing in columns of the ordinary width and in very narrow columns, with the belief that the speed-tests, etc., taken in this side problem, would be valuable and, especially, suggestive for the larger study yet to be made.

I. COMPARISON OF SPEED IN VERTICAL AND IN HORIZONTAL READING.

It would seem that in reading matter printed in sufficiently narrow columns the eye's lateral movement might be eliminated or nearly so, and the reading be done with one downward sweep of the eye. Among the advantages to be expected from such reading might be mentioned (1) the very great decrease in the work of the oculo-motor muscles; (2) the elimination of the asymmetrical change in accommodation, which Javal (*Rev. Scientifique*, *1879*,) mentions as one of the main causes of fatigue in reading ordinary lines; (3) whatever advantage may be incident to having within the range of clear vision as much as possible of immediately related matter; (4) facilitation of the process of skimming.

I have confined myself to a comparison of speed, and have made the narrow columns contain but one word to the line, *i. e.*, having the center of each word just over the center of the next succeeding word.

Experiment A. There were printed on a Remington typewriter 15 lists of 50 words each in nonsense-arrangement, even similarity of first and last parts of words being avoided, and no two alike, in vertical column; and each list was also printed in ordinary horizontal fashion, but in reverse order of words, the lines being made a little shorter than the length of the columns, the type and other conditions similar in horizontal and in vertical lists. The first list contained only words of two letters; the second, words of three letters, etc., to and including a

list of 16-letter words. A list of 50 letters of the alphabet, in nonsense-arrangement, was added, with its reversed form as with the word-lists.

As the typewriter gave the same space to each letter regardless of the letter's form, all the words of a list were of equal length and both margins were straight.

The lists were read aloud by the subjects as fast as possible. The time was taken with a stop-watch marking fifths of second nominally, though tenths could be read from it. The readings were made as follows: The list of two-letter words would be read, *e.g.*, first in the horizontal arrangement, then in vertical; then in vertical again, then in horizontal; then horizontal of the 3-letter list would be read, and a similar order would follow. Care was taken to arrange the order of tests so as to eliminate the errors due to practice, etc.

There were thus two comparisons (two horizontal readings and two vertical readings) for each of the 16 lists. The four subjects tested are members of this University as are the subjects serving in other tests presently to be mentioned.

The results may be found in Table I.

It is interesting to observe that while the shorter words are read more rapidly in horizontal sequence, the longer are read more rapidly in vertical. Though the mean variations are large, the relation is so frequently repeated that it seems not wholly accidental.

Experiment B, 1. In this test the subjects read aloud as fast as possible a sense passage of 300 words, divided into 6 parts of 50 words each. The whole passage was printed in both horizontal and vertical arrangement. The lines of the horizontal arrangement were about two-thirds the length of the vertically printed columns.

Owing to the great difficulty of printing or type-writing words with centers in a vertical line, as half spaces would be needed for words of an odd number of letters, the arranging in vertical columns was done by hand, the words being cut from an exact duplicate of the horizontal copy used in the experiment and pasted on a background of white paper, the columns being placed as close to each other as the length of the longest words would allow. One reading of the passage was then taken, fifty words at a time, the first fifty being read vertically, second 50 horizontally, third vertically, and so throughout. Some days later, a second reading was taken, the parts read in vertical arrangement at the first reading being now read horizontally, and *vice versa*.

TABLE I.

Showing average times for reading aloud at maximal speed the same (nonsense) material in vertical and horizontal arrangements.

No. Letters		W.		C.		P.		H.		Av. 4 Subjects.	
		T.	M. V.	T.	M. V.	T.	M. V.	T.	M. V.	T.	M. V.
1	V	17.1	.3	16.5	.6	15.9	1.3	13.4	.8	15.7	.75
	H	15.8	.5	13.9	1.0	14.5	.5	12.2	.2	14.1	.55
2	V	18.1	.5	18.2	2.6	16.8	.8	15.8	.2	17.2	1.00
	H	15.8	1.0	17.5	1.8	17.3	1.3	12.0	.8	15.7	1.20
3	V	18.1	.8	17.3	1.8	15.5	1.1	15.3	.1	16.6	.95
	H	15.1	1.4	17.2	1.2	16.4	1.6	11.4	1.4	15.0	1.40
4	V	19.0	1.1	19.3	1.3	15.4	.6	15.3	1.3	17.3	1.08
	H	16.1	.3	19.9	.7	16.4	1.6	12.0	.8	16.1	.85
5	V	18.3	.8	18.7	2.1	14.1	.1	15.6	.6	16.7	.90
	H	17.0	.6	20.3	.3	15.9	1.1	14.1	.3	16.8	.58
6	V	17.6	1.7	23.4	3.4	16.3	.5	16.2	.4	18.4	1.50
	H	16.4	1.7	22.0	2.8	19.7	2.5	14.6	.8	18.2	1.95
7	V	17.7	1.4	20.8	1.8	17.1	.3	15.8	.4	17.9	.98
	H	15.2	.4	22.0	.2	16.1	.3	14.5	.7	17.0	.40
8	V	19.5	.7	21.2	.8	20.0	.8	17.8	.0	19.6	.58
	H	18.2	.7	25.3	3.5	20.1	.9	15.9	.3	19.9	1.35
9	V	21.1	.3	23.6	1.0	23.0	2.6	18.9	.3	21.7	1.05
	H	20.3	.2	25.2	4.2	20.8	1.0	18.0	.4	21.1	1.45
10	V	22.9	.8	25.5	.3	23.2	1.2	21.1	1.1	23.2	.85
	H	22.6	.6	27.0	3.6	22.7	1.5	19.7	.3	23.0	1.50
11	V	24.7	1.2	32.7	2.5	25.8	1.0	23.3	.7	26.6	1.35
	H	24.5	1.1	30.0	2.8	28.3	2.7	21.7	.3	26.1	1.73
12	V	28.5	3.3	33.1	.3	28.2	.6	24.3	.1	28.5	1.08
	H	25.9	.9	34.8	3.7	29.7	2.2	24.5	.9	28.7	1.93
13	V	28.9	1.0	35.2	.6	27.9	.3	26.0	.0	29.5	.48
	H	26.2	.5	39.3	7.1	30.6	.2	27.2	.6	30.8	2.10
14	V	31.9	.8	35.9	.3	34.3	1.5	32.9	.1	33.8	.70
	H	32.2	2.5	40.7	6.3	36.5	1.5	32.0	.8	35.4	2.78
15	V	37.0	1.6	55.8	4.2	40.8	2.0	38.5	1.0	43.0	2.20
	H	35.8	1.8	60.5	8.5	48.0	7.5	35.3	3.7	44.9	5.40
16	V	42.5	3.8	68.0	1.6	53.0	3.0	53.0	3.0	54.1	2.85
	H	44.5	1.7	69.3	5.1	59.7	7.5	59.7	7.5	58.3	5.45
Av. V.		23.9	1.26	29.1	1.56	24.2	1.11	22.7	.63	25.0	1.14
Av. H.		22.6	.99	30.3	3.30	25.8	2.12	21.55	1.20	25.1	1.91

The results for three subjects are as follows:

TABLE II.

Showing average time for reading sense passages in vertical and horizontal arrangement.

	VERTICAL.			HORIZONTAL.		
	Av. time per 50.		Words per sec.	Av. time per 50.		Words per sec.
	T.	M. V.		T.	M. V.	
P.	10.47	1.1	4.78	10.55	1.2	4.74
K.	14.40	.5	3.47	12.00	1.5	4.17
B.	14.13	1.9	3.54	12.00	2.0	4.17
Av.	13.00	1.2	3.93	11.52	1.6	4.36

Experiment B, 2. The same test was also made in a somewhat different form. This time the subjects read a sense passage of 323 words, aloud, as fast as possible, continuously, by one method (vertical or horizontal) and immediately read the same passage by the other method. The arrangement in vertical columns was as in the preceding experiment. After some days the reading was repeated, the order being reversed. Results for four subjects follow in Table III.

TABLE III.

Showing maximal speed of reading a sense passage aloud.

	VERTICAL.			HORIZONTAL.		
	Av. time for 323.		Words per sec.	Av. Time for 323.		Words per sec.
		M. V.			M. V.	
P.	75.05	6.0	4.30	75.3	2.2	4.29
K.	74.45	2.4	4.34	66.45	5.5	4.86
H.	62.10	1.9	5.20	59.1	.5	5.47
D.	109.00	11.4	2.97	99.90	5.1	3.23
Av.	80.15	5.4	4.20	75.19	3.3	4.46

Experiment C. This test was an exact duplicate of the preceding one, except that the reading was done silently instead of aloud. The subjects were directed to read it all, but by their own fastest method, and to pronounce the last word as a signal for the time-taker. Below are the results for five subjects:

TABLE IV.

Showing maximal speed of reading sense-passage silently.

	VERTICAL.			HORIZONTAL.		
	Av. Time for 323.		Words per sec.	Av. time for 323.		Words per sec.
		M. V.			M. V.	
P.	64.60	10.2	5.00	48.55	4.9	6.65
J.	121.80	6.2	2.65	83.70	0.1	3.86
K.	46.65	1.4	6.92	34.00	1.2	9.50
D.	65.15	6.7	4.96	31.40	3.1	10.30
B.	69.90	7.9	4.62	43.65	.15	7.40
Av.	73.62	6.5	4.83	48.26	1.9	7.54

In all these tests with words making sense the advantage is with the horizontal reading, but it is well to remember that the vertically arranged matter of all the sense-passages had been pasted on the page word by word ; and in spite of all care the page presented an appearance more or less different from that of a neatly printed one. The distraction of attention incident to this, and to the vertical arrangement in general, would seem to be greater in silent reading, when no sound of the voice was present to help guide the attention and make visual distractions relatively unimportant. The smallness of the gain in speed in silent reading by the vertical method may be due to this, at least in part.

The enormous amount of practice in horizontal reading, which all subjects have had, must of course be taken into account in any such comparison. Subjects say they can easily read straight down with one downward sweep of the eye ; but that they forget and use the old side-to-side method, taking, of course, more time with such short lines.

Then again, it is probable that the subject may have a greatest possible speed by one method and a greatest normal speed, or speed of comfortable and intelligent reading, by quite another.

Miscellaneous Observations. The readings furnished data of considerable interest aside from the immediate purposes of this comparison.

Rate for words of different length, for instance, in Table I dissyllables (6 letter-list) take but little more time than monosyllables (4-letter list) in reading aloud (18.2 : 16.1). A five-fold increase in length of words (3-letter to 15-letter lists) causes only a three-fold (15 : 44.9) increase in time ; this, too, though the long words were much less familiar. Single letters are seen to take almost as much time as short words, as already observed by Cattell.

Effect of Practice. In Table V below is shown the time of first and eighth readings of some of the 50-word nonsense-lists. The first and eighth readings were by the ordinary horizontal method. Between these were four readings in reverse arrangement and only two in the direct, owing to the peculiar conditions of the experiment. It would seem, then, that the practice in word-order was negative, if anything ; and that the increase in speed was due to increasing familiarity with the words themselves.

The test taken on myself, subject "Hu," indicates that there is a point beyond which further familiarity with the words does not very appreciably increase the speed. In arranging the lists and in the experiments I had become very familiar with every word ; and this no doubt accounts for the constancy of speed.

TABLE V.

Time, in seconds, for first and eighth reading of 50 words in nonsense arrangement, at maximal speed, aloud and intelligibly.

	Single letters.		5-letter words.		9-letter words.		13-letter words.		Average.	
	1st R.	8th R.	1st R.	8th R.	1st R.	8th R.	1st R.	8th R.	1st R.	8th R.
P.	15.0	15.6	17.0	14.6	21.8	21.6	30.4	25.2	21.05	19.25
C.	14.8	11.9	20.0	18.4	29.4	20.8	46.4	29.4	27.65	20.12
W.	16.8	12.4	19.0	17.8	21.3	19.8	29.8	26.1	21.73	19.03
Hu.	12.0	11.6	14.4	15.0	17.6	17.4	27.8	27.0	17.95	17.75
Av.	14.7	12.9	17.6	16.5	22.5	19.9	33.6	26.9	22.10	19.05

Reading of Sense and Nonsense Matter. The speed in reading aloud was found to be closely correlated with the "sense" made, as might have been expected. Sense-passages were read in little more than half the time taken for nonsense-passages having an equal number of letters. There seems to be a *camaraderie*, as Egger calls it, among our words, and even among our phrases and sentences; and pronunciation of an adjective, for example, seems to subexcite association tracts representing substantives; — preferably and more strongly the substantives with which the particular adjective has been most often associated. Of these subexcited substantive tracts, some are still more excited by closer association with the general subject under discussion in the matter read. The right word, then, is ready to leap out at the slightest suggestion from the printed page, if that passage makes sense. If, however, it does *not* make sense; — if a preposition, *e.g.*, follows the adjective, the utterance of the former must suffer a loss of time due to lack of association in the past between adjectives and prepositions — there is no sub-excitation, to speak in physiological terms, of the organs for pronunciation of the preposition. Indeed, there is more than that; there is an interference of associations such as Bergström investigated in his card dealing experiment.[1] So in certain positions the substantive tends to arouse verbs, the preposition its related object, etc.[1]

II. COMPARISON OF THE IMPORTANCE FOR WORD RECOGNITION OF THE FIRST AND LAST PARTS OF WORDS.

A passage of sense-reading containing 456 words was printed in ordinary fashion, making a page of 43 lines, with considerable paragraphing. Several copies of this were obtained. From one copy the exact first half of each word was cut out,

[1] See *Am. Journal Psych.*, Vol. V, 356, ff. Art. on Experiments upon Memory.

letters being cut in half when necessary; and from another copy the latter half was similarly cut out. The arrangement is illustrated below:

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any features of such a scheme? If this does not appeal to you, then will you kindly, from a more practical standpoint, state the changes and reforms most greatly needed? Our purpose is to combine these views, statistically and otherwise, and to send a printed copy to each contributor.

The items below merely suggest leading topics. Select those you are most interested in and add any others.

Each page thus honey-combed, was fastened closely upon a white paper background. The page was then marked off into four divisions. Two readings were taken, separated by several days. The subjects read the entire passage at each sitting. At the first reading, *e.g.*, the subject would read the first division of the passage, with the first half removed; then the second division with the latter half removed, and so alternating. At the second reading he would read the first division with the latter half removed, then the second division with first half removed, and so reversing the order throughout. The passage used had not been read by the subjects previous to the experimental reading. The subjects were directed to read as fast as they could consistently with making as good sense as possible, but not to feel that they "had to hurry." They read aloud, the experimenter following the reading on a duplicate copy, and marking the words read correctly. The time spent on each division was taken with the stop-watch, the subject giving a signal when he reached the end of a division, never returning to correct mistakes. The first division contained 163 words, the second 125, the third 111, the fourth 57. Below are the results for three subjects:

TABLE VI.

Comparative importance for word-recognition of the first and last halves of words.

Subjects.	Part removed.	FIRST READING.					SECOND READING.					TOTAL BOTH READINGS.				
		Time (in seconds.)	Words in passage.	Words read correctly.	Per cent. read correctly.	Words read correctly per second.	Time (in seconds.)	Words in passage.	Words read correctly.	Per cent. read correctly.	Words read correctly per second.	Time (in seconds.)	Words in passage.	Words read correctly.	Per cent. read correctly.	Words read correctly per second.
K	1st half ..	638	274	207	75.6	.32	361	182	144	79.1	.40	999	456	351	77.4	.35
	2d half...	427	182	159	87.4	.37	369	274	253	92.3	.68	796	456	412	89.9	.52
J	1st half ..	767	182	62	34.1	.08	836	274	168	61.3	.20	1603	456	230	47.7	.14
	2d half...	1113	274	189	69.0	.17	555	182	153	84.1	.28	1668	456	342	76.6	.21
V	1st half ..	423	274	219	79.9	.52	322	182	153	84.1	.48	745	456	372	82.0	.50
	2d half...	238	182	161	88.5	.68	332	274	253	94.9	.76	570	456	414	91.7	.73
Total	1st half .	1828	730	488	66.9*	.31*	1519	638	465	72.9*	.36*	3347	1368	953	69.9*	.33*
	2d half...	1778	638	509	79.8*	.41*	1256	730	659	90.3*	.57*	3034	1368	1168	85.1*	.49*

NOTE.—The starred numbers are averages from the vertical columns in which they stand, not recalculations from the totals to the left of each.

Among the factors that co-operate in this result may be mentioned (1) the tendency of English to place the accent on the first part of the word, the accented part tending to represent the word, at least the spoken word; (2) the preponderance of suffixes over prefixes, the main root of the word being in the first part, thus rendering the first part more important,

It seems probable also that the time-order in ordinary inter-association of syllables and other divisions of words has much to do with the difference shown. This time-order has almost always been from the first toward the latter part; and, as has been shown by various experiments, associations do not work nearly so well in reverse time-order.

III. Movements of the Eye in Reading.

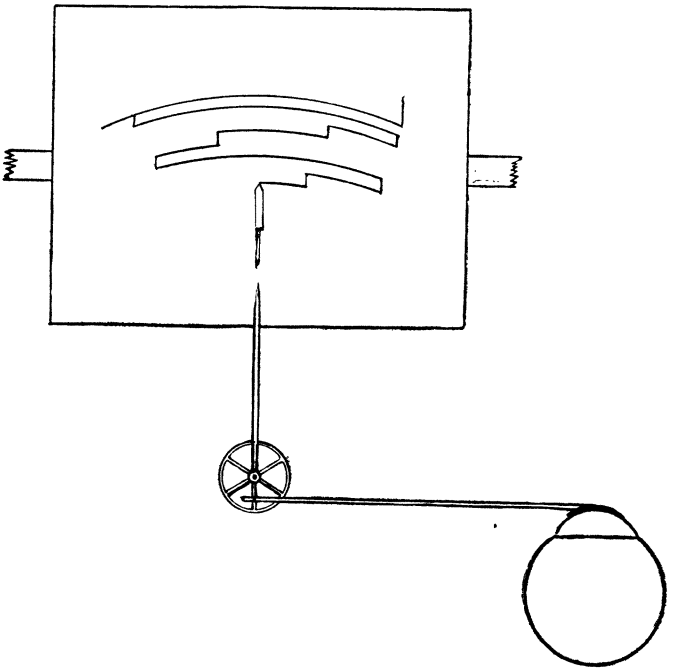
By watching the eyes of subjects while reading matter such as a page of this JOURNAL, I found that I could always tell them, at the end of a passage, just how many lines they had read, despite their subjective notions that their eyes did not sweep along each line. By having the subject read aloud and noting the syllable pronounced just as the eye turned for the return sweep, I found that I could get the approximate distance of the eye ahead of the pronunciation, for at least one point in the line.

Besides, the most casual observation showed that the eye moved along the line by little jerks and not with a continuous steady movement. I tried to record these jerks by direct observation, but finally decided that my simple reaction to sight stimuli was not qnick enough to keep up with them when the subject read at normal speed.

It seemed needful to have an accurate record of these movements; and it seemed impossible to get such record without a direct attachment of recording apparatus to the eye-ball. As I could then find no account of this having been done, I arranged apparatus for the purpose and have so far succeeded in taking 18 tracings of the eye's movements in reading as many passages consisting of from 9 to 30 lines each, in different sizes of type and with lines varying in length from 21 mm. to 120 mm.

The apparatus consists essentially of (1) a frame for fixation of the head, fastened between iron standards which are clamped to a heavy table; (2) of a light recording arrangement, resting on the top of one of the standards, connecting by a light celloidin-covered glass lever with a cup capping the cornea, and writing its record on the smoked drum of a kymograph by means of a celloidin-tipped tubular glass pointer, (below is a somewhat simplified horizontal plan of the arrangement for recording); (3) of an electric time-marker wired to a clock

marking quarter-seconds, and writing its record on the drum just opposite the record of eye-movements; (4) of a holder for the reading matter, arranged to slide on a track bearing a scale of distances measured from the front of the cornea.



A permanent fixation of the head with reference to the recording apparatus and reading matter is obtained by having the subject bite into a mass of partially cooled sealing-wax attached to a mouth-piece fastened in the head frame; the imprint of the teeth being preserved when the wax hardens.

The cups used for attachment to the cornea were made by casting plaster-of-Paris over either a carnelian marble or a steel ball having a radius of curvature a very little less than that of the cornea. The outer surface of the cups was sand-papered until quite thin and light and a hole was drilled through the center, of a diameter of 1.7 mm. The cup has been placed on the left eye, in experiments thus far.

As may be seen from the diagram above, there was no weight on the eye but that of the cup and short lever directly attached to it; and the work of the eye-muscles needed to run the recording-apparatus is almost imperceptible in actual reading.

The eyelids are kept separated and the subject prevented from winking by lead fingers fastened to the head frame and pressing sufficiently upon the skin above and below the eye.

The eye was rendered anæsthetic by the use of cocaine. Beyond the dilation of the pupil (corrected by the cup acting as a diaphragm), and an occasional interference with accommodation, the normal action of the eye seemed to be in no way interfered with.

In beginning each test the eye was fixated on the left end of the first printed line, or of two or more parallel ink lines drawn above this. When the kymograph had attained its proper speed, at a signal from the assistant, the eye was moved along the line and fixated on the other end, then back, and so on, back and forth for from two to five lines before the reading began. This was done to furnish known bases for comparison with the later curves. The curves show no interruption from end to end, until the reading begins. Then, however, the curve is not only *always* interrupted by the eye's several fixations, but is always shorter than the curve representing the lines whose ends were fixated, showing that the eye does not travel the entire length of the line in reading.

In some of the tests the ends of the last two lines were fixated also, and probably this will be found most convenient for purposes of measurement. By reading the same matter at different distances from the eye, the number of jerks was shown to be a function of the matter read rather than of the arc described by the eye's rotation.

A series of eight tests was taken with special reference to determining what function the lateral movement of the eye is of the length of the line, and with what width of column the lateral movement may cease and the reading be done with one downward sweep of the eye. The passages used were cut from *Munsey's Magazine* and the *Cosmopolitan*, and were in their ordinary size of type, with lengths of line varying between 21 and 120 mm.

The tests show at a glance that the lateral movement decreases much faster than does the length of the lines and that at 21 mm. the reading may be done without lateral movement, though this is still apt to occur, probably from habit.

By the help of the quarter-second record written on the margin of the paper, it is possible to measure approximately the time during which the eye remains fixated at each point, but the unit is too large for getting the speed with which it moves from one fixation point to another.[1] The latter point is espe-

[1] A promising attempt has been made to measure this by means of the spark method of time recording.

cially interesting, as it would seem from the curves that the speed may be so great that the retinal impressions fuse and that we really do not see foveally what we read except at the few points on the ordinary line at which the eye pauses. These experiments are as yet incomplete; and the data which they furnish cannot be arranged in time for this report.

For the suggestion of making a direct attachment to the eyeball, I am indebted to Dr. August Ahrens[1] who reports making a firm attachment of an ivory cup, but failed to record the movements. I am told that cups of glass have also been attached, in ophthalmological practice. I am also indebted to Prof. Delabarre for the suggestion of plaster-of-Paris as a most convenient material, and this has been used thus far, ivory cups being rather troublesome to make, while the plaster-of-Paris is easily workable.

No trouble was experienced in getting the cup to stick for as long as was desired, when the lids were kept well separated; indeed, it was somewhat difficult to remove it on several occasions. The experiments have so far been made on but two subjects — Prof. Hodge and myself. I am especially indebted to Prof. Hodge, as it has been difficult to get subjects; partly from an exaggerated notion of the danger to the eye, partly from the defective vision of those who were otherwise available.

[1]See his "Die Bewegung der Augen beim Schreiben," Rostock, 1891.